Appendix B Evaluation of the Impact of Timber Harvest on Future Potential Recruitment of Large Woody Debris in Class I Watercourses

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Riparian management zones (RMZs) provide several important biological and watershed functions. In addition to functions such as maintaining the riparian microclimate and providing nutrient inputs, one of the most important functions of the RMZs is to provide for the recruitment of large woody debris (LWD) to the watercourse. LWD is recognized as a vital component of salmonid habitat. The physical processes associated with LWD include sediment sorting and storage, retention of organic debris, and modification of water quality (Bisson et al. 1987). The biological functions associated with LWD structures for the salmonid species include important rearing habitats, protective cover from predators and elevated stream flow, retention of gravels for salmonid redds, and regulation of organic material for the in-stream community of aquatic invertebrates (Murphy et al. 1986; Bisson et al. 1987). Decreased supply of LWD can result in increased vulnerability to predators, reduction in winter survival, reduction in carrying capacity, reduced spawning habitat availability, reduction in food productivity and loss of species diversity (Hicks et. al. 1991 as cited by Spence et. al. 1996). Long-term reductions in LWD can result in less stream complexity and reduce the amount of high quality rearing habitat for salmonids and other fish species.

The minimum width of RMZs on Class I (fish bearing) watercourses is 150 feet with 85% overstory canopy retention in the inner zone (50-70 feet depending on slope class) and 70% overstory retention in the remaining outer zone. However, probably the most important measure relative to the potential recruitment of LWD is that no trees will be harvested that are judged likely to recruit to the watercourse. There are a variety of criteria that will be used to make this judgment including, but not restricted to, distance from the stream, direction of the lean, a clear fall path to the channel, and potential for stream undercutting. However, some of these criteria are inherently subjective and concerns have been raised that the “likely to recruit” language in Green Diamond’s draft Aquatic Habitat Conservation Plan/Candidate Conservation Agreement with Assurances (AHCP/CCAA) is not sufficient to insure that there will be no loss of important future LWD. Numerous attempts were made to improve the likely to recruit language, but none were entirely successful. As a result, the Services (NMFS and the Fish and Wildlife Service) and Green Diamond agreed to gather empirical data from Watercourse and Lake Protection Zones (WLPZs) in Class I watercourses to assess the extent to which current guidelines were successful in maintaining future potential LWD. The objective of this study was to gather data from WLPZs that have been marked, but not yet harvested, and from those that already have been harvested, following Green Diamond’s internal guidelines relative to retaining trees that are likely to recruit.

To permit quantification of future potential LWD, we made several assumptions concerning recruitment and quantified trees in terms of "Full Tree Equivalents" (FTE). One FTE is defined as a tree with a probability of 1.0 that it would some day fall into the stream and eventually become a "fully functional" piece of LWD. Fully functional LWD interacts with the hydrology of the stream in such a way that it provides for all the benefits described above. To calculate FTE's, we developed a tree recruitment potential model based on tree height and the distance of each tree from the channel. The model assumes the stream is a straight line and each tree has an equal probability of falling in any direction. The FTE was calculated as the proportion of an area of a circle that extends beyond the closest watercourse transition line (WTL). The circle was circumscribed by the falling radius of the tree. For example, a 150-foot tall tree located 100 feet from the WTL has the potential to fall into the channel with a maximum of 50 feet of the tree being recruited. The FTE value of this tree would be 0.110 meaning that 11.0% of the area of the circle represented by the falling radius of that tree could extend beyond the WTL and into the channel. This calculation gives a greater weighting factor to trees that would provide greater functionality to the stream in terms of having a greater proportion of the tree potentially interacting with the fluvial processes of the stream. A tree that is farther from the WTL than it's height received an FTE value of 0.0. A tree located within the WTL (growing within the active channel) received a FTE value of 1.0. These trees were considered recruited and 100% functional regardless of the falling direction. We also assumed that 10" DBH was the minimum size tree that would be functional in most Class I watercourses. Quantifying of the impact of timber harvest on the potential recruitment of LWD was based on the summation of FTE's before and after harvest of trees greater than or equal to 10" DBH.

The initial analysis was based on the current height of trees in the WLPZ, recognizing that most trees will continue to grow and will not recruit (blow down, be recruited by fluvial or geological processes or die and fall into the watercourse) for many years into the future. Green Diamond recalculated potential impacts from tree harvest within the RMZ after adding 50 years of average growth to the trees in the WLPZ. This provided a view on recruitment potential of trees within the WLPZ retained on site for the life of the permit. The difference in impacts from harvesting on FTE's at current rotation age versus impacts at rotation plus 50 years could then be evaluated.

Field Methods

Five Class I WLPZs were inventoried for LWD recruitment potential. Two of these WLPZs were located in Maple Creek (T8&9N, R1E HBM) and three in Ryan Creek (T4N, R1E HBM). The two WLPZs in Maple Creek were each from separate THPs that were harvested and logged during the summer of 2003 (Attachment A, Figures A1 and A2). The three WLPZs in Ryan Creek were located within a single Timber Harvest Plan (THP) unit that had been laid out and marked, but had not been harvested (Figure A3). All the WLPZs were administered under the Threatened and Impaired Watershed package of the California Forest Practice Rules and therefore are nominally 150 feet wide.

The inventory crews worked in groups of four. One person with a hip chain walked the stream channel along the edge of the riparian zone. This person took notes, kept track of channel distance for each conifer, measured the channel gradient (every 300') and kept the rest of the crew in a perpendicular line with the stream as they measured the conifers and snags in the WLZP. The upslope crewmembers measured the DBH, the distance of the tree from channel (Y coordinate), distance up the channel (X coordinate), hillslope gradient, and noted the species of any conifer tree that was 10" DBH or larger. DBH was measured with a Biltmore stick to the nearest inch at 4.5' on the uphill side of any standing tree. Each standing conifer was evaluated for an obvious lean of greater than or equal to 5 degrees from vertical. If a tree had an obvious lean, the angle of lean and the direction of lean were measured in relation to the stream channel. A tree that was leaning perpendicular towards the channel was given a direction of lean of 90 degrees. Therefore 0 to 179 degrees was assigned to trees with a downslope direction of lean and 180 to 359 degrees to trees with an upslope direction of lean. The diameter, height, species and decay class of all snags greater than 10" DBH were noted. In the unharvested WLPZs, each tree that was marked for harvest was noted as a "stump". A marked tree typically has a blue painted stripe and a basal mark. It was assumed that all trees that were marked will be harvested when the THP unit is operated. In the harvested WLPZs, the species, diameter and location (X and Y coordinates in relation to the channel) of stumps of the recently harvested trees were noted.

Within each sampling location, a representative sample of conifer trees of each species (grouped by redwood and other conifer) were measured for tree height in addition to DBH. Trees selected for height measurement were representative dominant and co-dominant trees of the WLPZ. The actual selection depended on the ability to see both top and bottom of the tree at a reasonable distance from the tree (e.g. within the % range of the clinometer). These sampled conifers were used to estimate the heights of the trees in the WLPZs.

Analysis

In order to calculate the FTE for each tree, the height of each tree was needed. The exponential form of the height-diameter model from Krumland and Wensel (1978) was used to estimate tree heights in the various WLPZs. The trees that were selected for height measurement were used in the model to develop individual height-diameter relationships for each WLPZ, except the data from Ryan Creek were pooled since the three WLPZs were in close proximity to each other. The FTE of each tree was then calculated and summed for the pre-harvest condition. The FTE of harvested trees (stumps) in the Maple Creek WLPZs were estimated from the diameters of the stumps. The post harvest condition was determined by setting the FTE value for each marked (Ryan Creek WLPZs) or harvested tree (Maple Creek WLPZs) to a value of zero. The difference between the summed pre-harvest FTE values and summed post-harvest FTE values was expressed as a percent post-harvest reduction in cumulative FTE for each WLPZ.

In order to evaluate the potential impact of harvest over the term of the permit, we assumed that all the WLPZs were in the 50 year age class and then grew the trees an additional 50 years. Based on the average site index for Green Diamond's property, we would expect redwood and Douglas fir in the 50-year age class to grow approximately 50 feet taller in 50 years. Conifer trees that were less than 10" DBH at the 50-year age class were not added to the analysis of the 100-year age class.

Additional information was measured and summarized for each of the WLPZs which could be used to adjust the FTE value of individual trees, numerically. This information can be used to refine the probability of individual trees being recruited to the stream channel based on the side slope gradient and the amount and direction of lean of individual trees. Each standing conifer was evaluated for an obvious lean and if present the angle of lean and the direction of lean were measured in relation to the stream channel. The channel and side slopes were also measured, in percents, and summarized for each WLPZ. The channel slope was measured approximately once every 300 feet of channel or at any obvious changes. A weighted average was then calculated for the entire channel. The bank slope measurements were treated similarly and presented as a range of slope values for the WLPZ. The analysis presented here assumed all the trees were vertical and had an equal probability of falling in any direction. No FTE values were modified to account for the amount or direction of lean or the slope gradient. The information was collected and presented for discussion purposes.

Results and Discussion

The cumulative FTE reduction is the total affect that timber harvest had (or will have once harvested), on the recruitment potential of conifers to the watercourse. Figures 1-5 are graphical representations of each measured live conifer, stump, and snag in relation to the WTL. A red circle with a radius equal to the corresponding tree height is drawn around each tree that was harvested (or will be harvested). Each stump's FTE is represented by the proportion of the circle that extends beyond the WTL. When a circle does not extend beyond the WTL, the pre-harvest FTE values equal zero. The reduction in FTE values for all WLPZs post-harvest ranged from 0.0 to 0.62% (Table 1). Fifty years from now, all the conifer trees within these WLPZs were assumed to grow on average 50 feet taller. If the same trees were marked within these WLPZs, but were harvested 50 years from now, the reduction in FTE values post-harvest would range from 0.29 to 1.58%. A summary of the pre- and post-harvest stand component within each WLPZ is presented in Attachment B.

In the three Ryan Creek WLPZs, we assumed that each tree that was marked for harvest will be cut when the THP unit is operated. We observed cases in the two Maple Creek WLPZs (which were harvested) where several trees where originally marked for harvest, but not actually cut. In a few instances an adjacent unmarked tree was traded for the marked tree. It is likely the timber fallers determined that cutting the marked tree would be unsafe or infeasible to fall. The marked trees may have been limb-locked or located behind another tree, an old growth stump or a snag. In some cases the faller would make a trade and sometimes decide not to cut anything from that particular area.

In the North Fork Maple WLPZ, 5 of 251 conifer trees were harvested (98.0% conifer retention). This equates to approximately 1 tree harvested for every 260 feet of WLPZ length. Of the 5 trees harvested, none had a FTE value greater than zero. The harvest of the 5 trees did not change the recruitment potential of the WLPZ (Table 1). If the harvest was delayed 50 years, 4 of the 5 trees harvested would have a FTE value greater than zero. This would result in a 0.29% reduction in the recruitment potential of conifers in the WLPZ (Table 1).

In the CR1500 WLPZ, 88 of 1115 conifer trees were harvested (92.1% conifer retention). This equates to approximately 1 tree harvested for every 25 feet of WLPZ length. Of the 88 trees harvested, 14 had a pre-harvest FTE value greater than zero. After harvest, the removal of the 14 trees resulted in a 0.62% reduction in the recruitment potential of conifers in the WLPZ (Table 1). If the harvest was delayed 50 years, 44of the 88 trees harvested would have a FTE value greater than zero. This would result in a 1.58% reduction in the recruitment potential of conifers in the WLPZ (Table 1).

In Ryan Creek Tributary #1, 8 of 296 conifer trees were marked for harvest (97.3% conifer retention). This equates to approximately 1 tree harvested for every 135 feet of WLPZ length. Of the 8 trees harvested, 7 had a pre-harvest FTE value greater than zero. After harvest, the removal of the 7 trees resulted in a 0.48% reduction in the recruitment potential of conifers in the WLPZ (Table 1). If the harvest was delayed 50 years, all of the trees harvested would have a FTE value greater than zero. This would result in a 1.20% reduction in the recruitment potential of conifers in the WLPZ (Table 1).

In Ryan Creek Tributary #2, 10 of 420 conifer trees were marked for harvest (97.6% conifer retention). This equates to approximately 1 tree harvested for 120 feet of WLPZ length. Of the 10 trees, 7 had a pre-harvest FTE value greater than zero. After harvest, the removal of the 7 trees resulted in a 0.23% reduction in the recruitment potential of conifers in the WLPZ (Table 1). If the harvest was delayed 50 years, all of the trees harvested would have a FTE value greater than zero. This would result in a 0.80% reduction in the recruitment potential of conifers in the WLPZ (Table 1).

An inexperienced crewmember, who was unfamiliar with the use of a Biltmore stick, created a minor bias in the calculation of total FTE for Ryan Creek tributary #2. The incorrect use of the Biltmore stick resulted in a positive bias of DBH on larger diameter trees and therefore an overestimation of tree height. This crew member only worked one of the three days it took to survey this WLPZ, and due to where he worked (within the first 50 feet from the channel and from a channel distance of 551 feet to 938 feet), the potential error can be evaluated as to its affect on the survey. There were no trees harvested from this area of the WLPZ. As a result the post-harvest FTE values were not reduced from activity in this part of the WLPZ. The pre- and post- harvest FTE calculations will be off by an identical amount resulting in a slightly higher cumulative FTE. Therefore any reduction in FTE due to harvest would have a slightly lower influence in the reduction in the overall recruitment potential of conifers.

In Ryan Creek Tributary #3, 10 of 521 conifers were marked for harvest (98.1% conifer retention). This equates to approximately 1 tree harvested for every 60 feet of WLPZ length. Of the 10 trees harvested, 7 had a pre-harvest FTE value greater than zero. After harvest, the removal of the 7 trees resulted in a 0.19% reduction in the recruitment potential of conifers in the WLPZ (Table 1). If the harvest was delayed 50 years, all of the trees harvested would have a FTE value greater than zero. This would result in a 0.63% reduction in the recruitment potential of conifers in the WLPZ (Table 1).

The pre- versus post-harvest difference in FTE indicated that timber harvest was having a very minor impact (maximum of <1%) on the cumulative total of future potential LWD recruitment. However, even more important is that the reduction comes from future LWD that has the lowest probability of becoming functional LWD. This is further supported by the analysis where the impact was evaluated over the life of the Plan. Fifty years from now, the pre- versus post-harvest difference in FTE would result in a maximum of <2% reduction of future potential LWD recruitment. Given this outcome, Green Diamond believes that its current internal guideline of not harvesting trees in Class I WLPZs that are likely to recruit is successful at maintaining a high level of future potential LWD recruitment.

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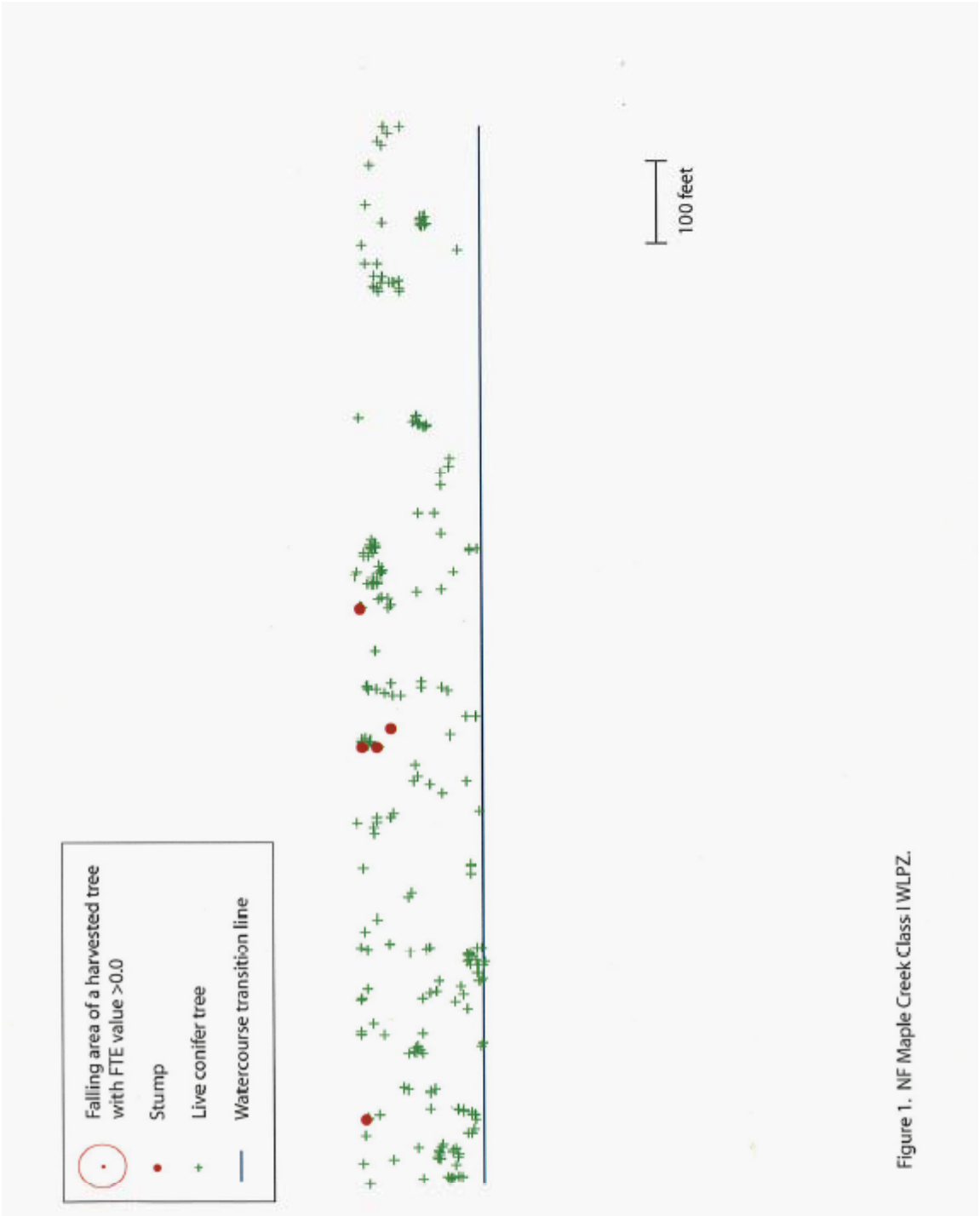

Figure 1. NF Maple Creek Class I WLPZ.

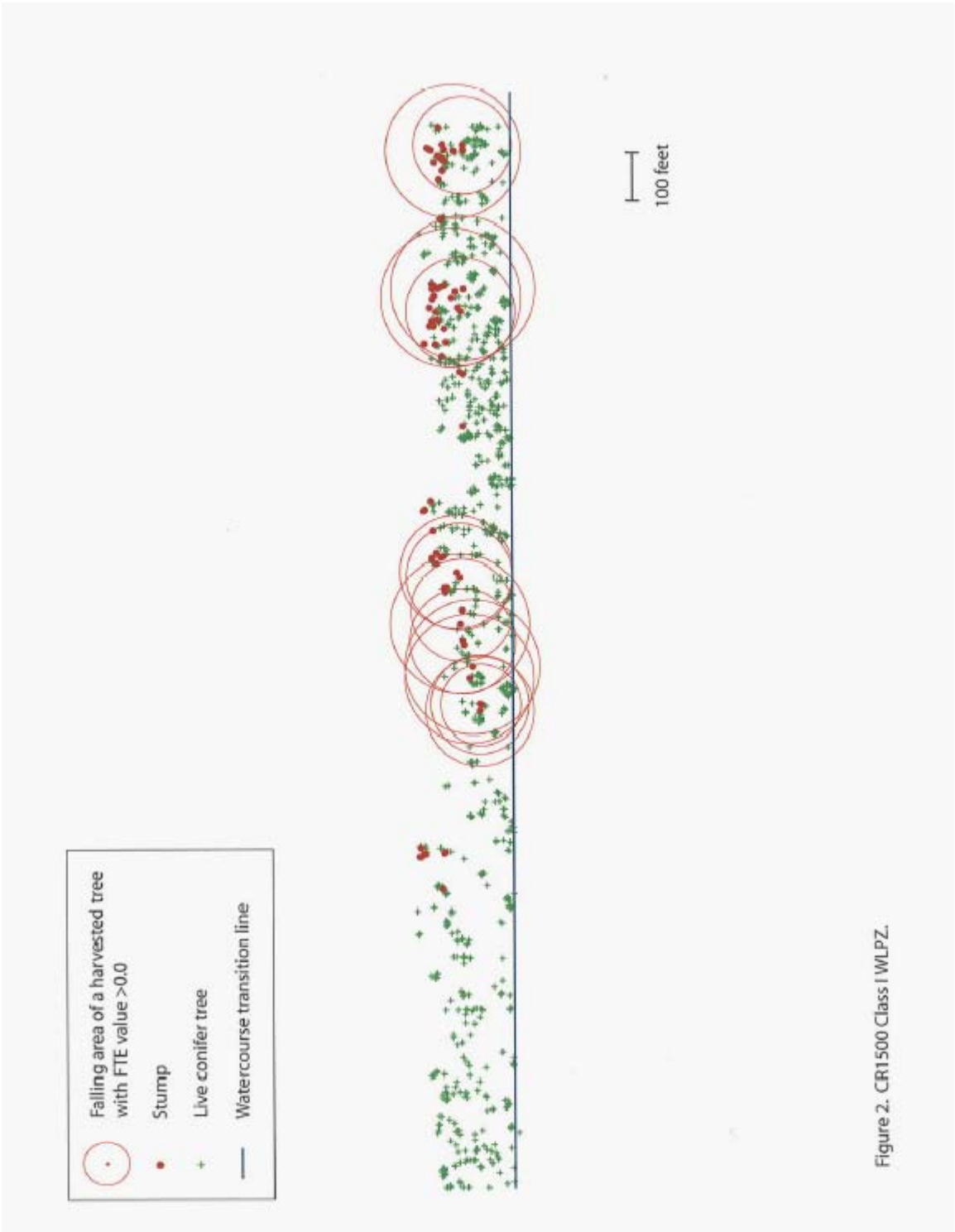

Figure 2. CR1500 Class I WLPZ.

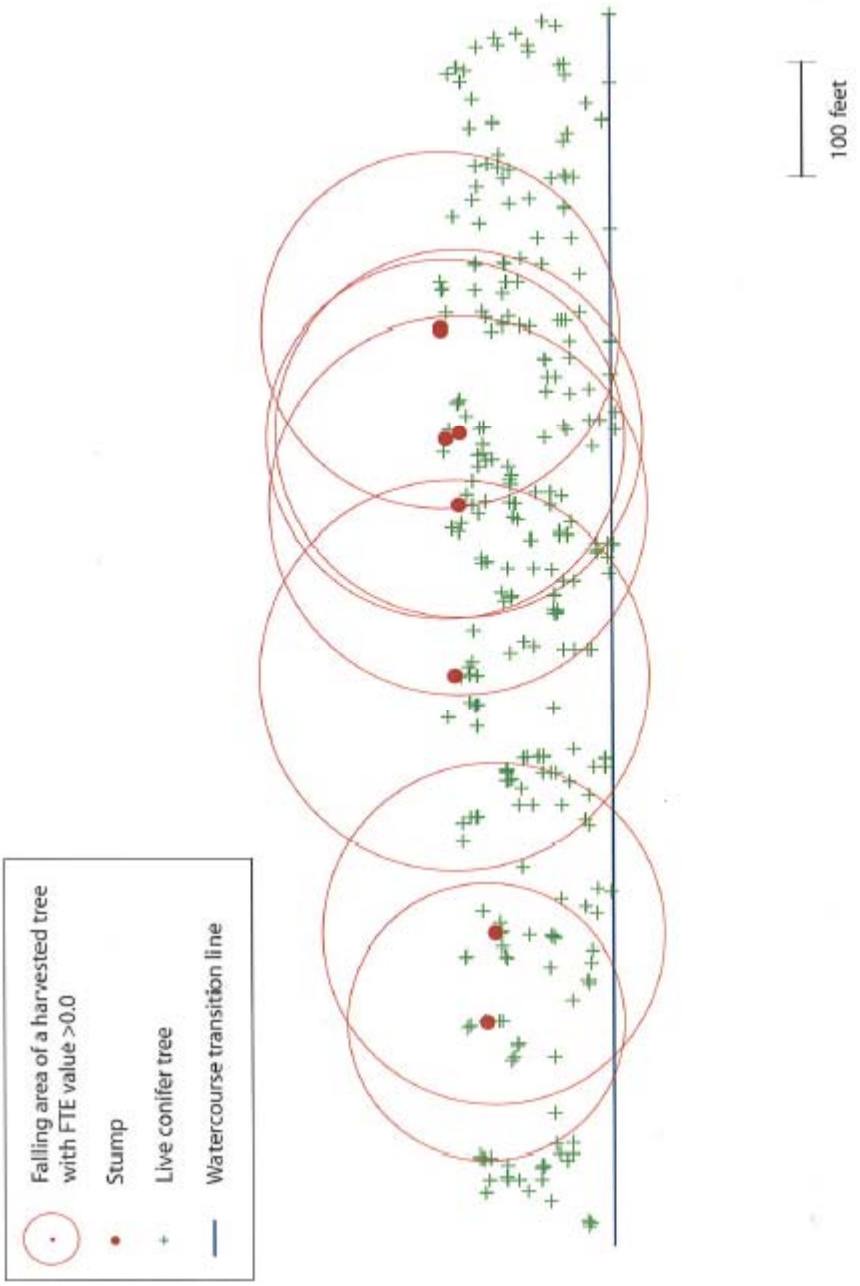

Figure 3. Ryan Creek #1 Class I WLPZ.

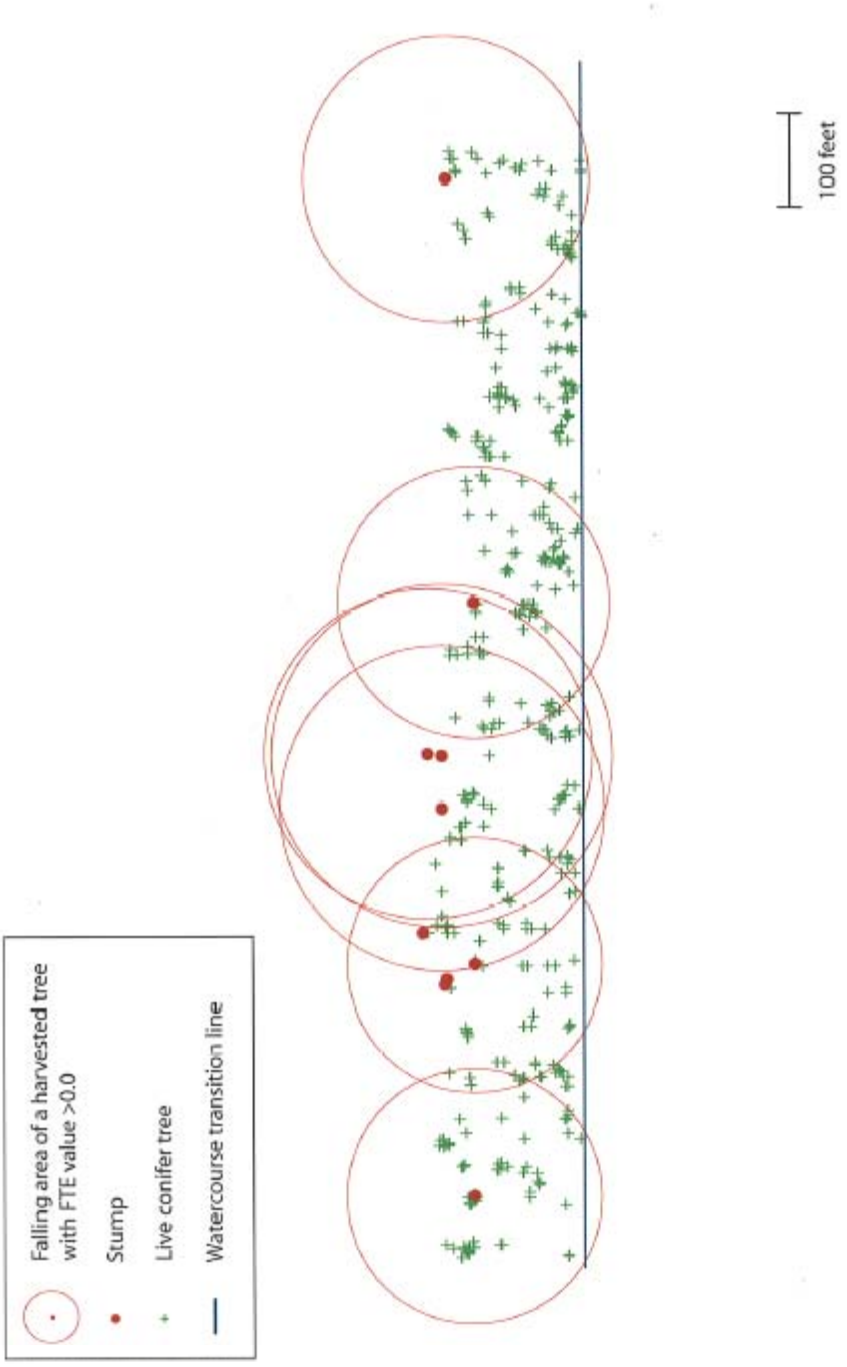

Figure 4. Ryan Creek #2 Class I WLPZ.

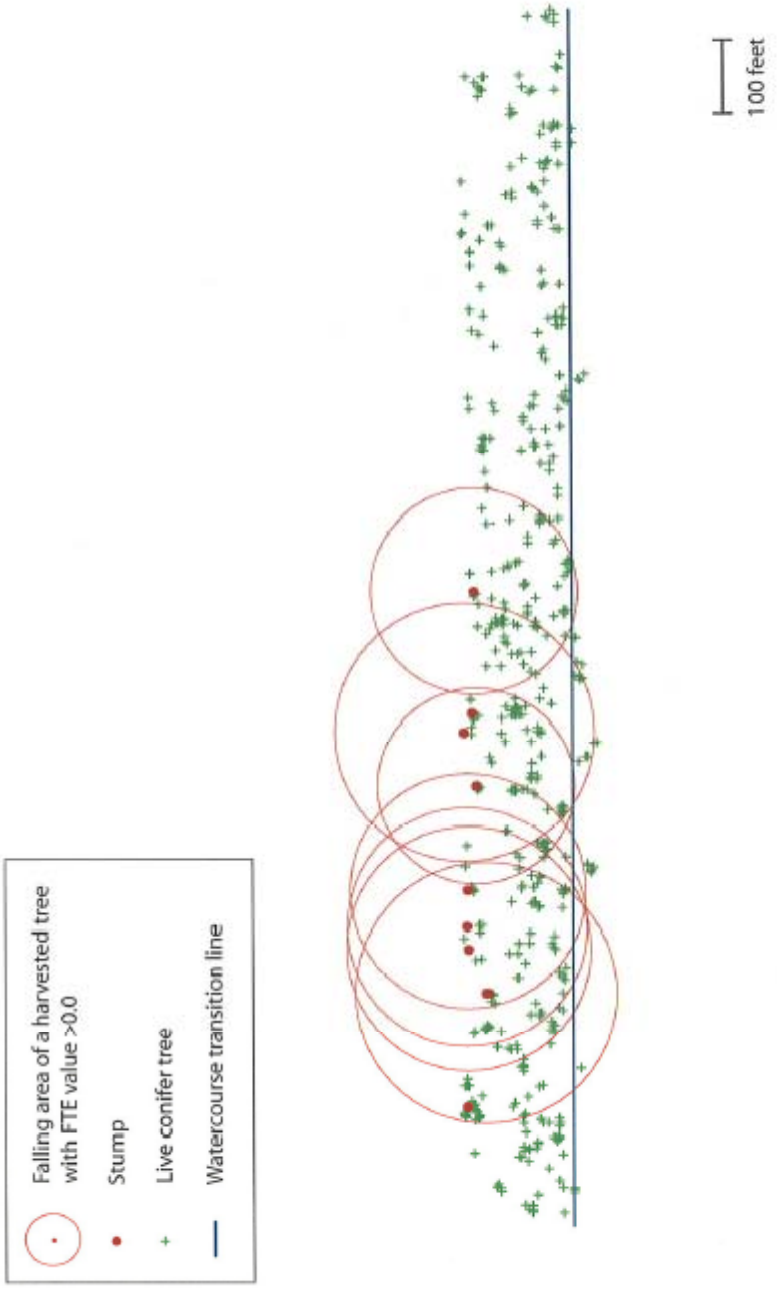

Figure 5. Ryan Creek #3 Class I WLPZ.

Table 1. Full Tree Equivalents (FTE) and associated parameters.

	Ryan #1	Ryan #2	Ryan #3	CR1500	NF Maple
Zone survey length (feet)	1086	1203	1689	2183	1299
Total # of live and recently harvested conifers in zone	296	420	521	1115	251
Total # of live trees marked or recently harvested	8	10	10	88	5
Percent conifer retention	97.3	97.6	98.1	92.1	98.0
Current Full tree equivalents (FTE)					
Pre-harvest	56.65	88.36	124.19	134.51	28.30
Post-harvest	56.37	88.16	123.95	133.68	28.30
Percent reduction	0.48	0.23	0.19	0.62	0.00
# of harvested trees with a FTE value >0.0 (current)	7	7	7	14	0
Predicted Full tree equivalents (+ 50 years)					
Pre-harvest	75.86	111.61	153.57	204.38	41.99
Post-harvest	74.95	110.72	152.59	201.15	41.87
Percent reduction	1.20	0.80	0.63	1.58	0.29
# of harvested trees with a FTE value >0.0 (+ 50 years)	8	10	10	44	4

Attachment A

Class I WLPZ survey areas

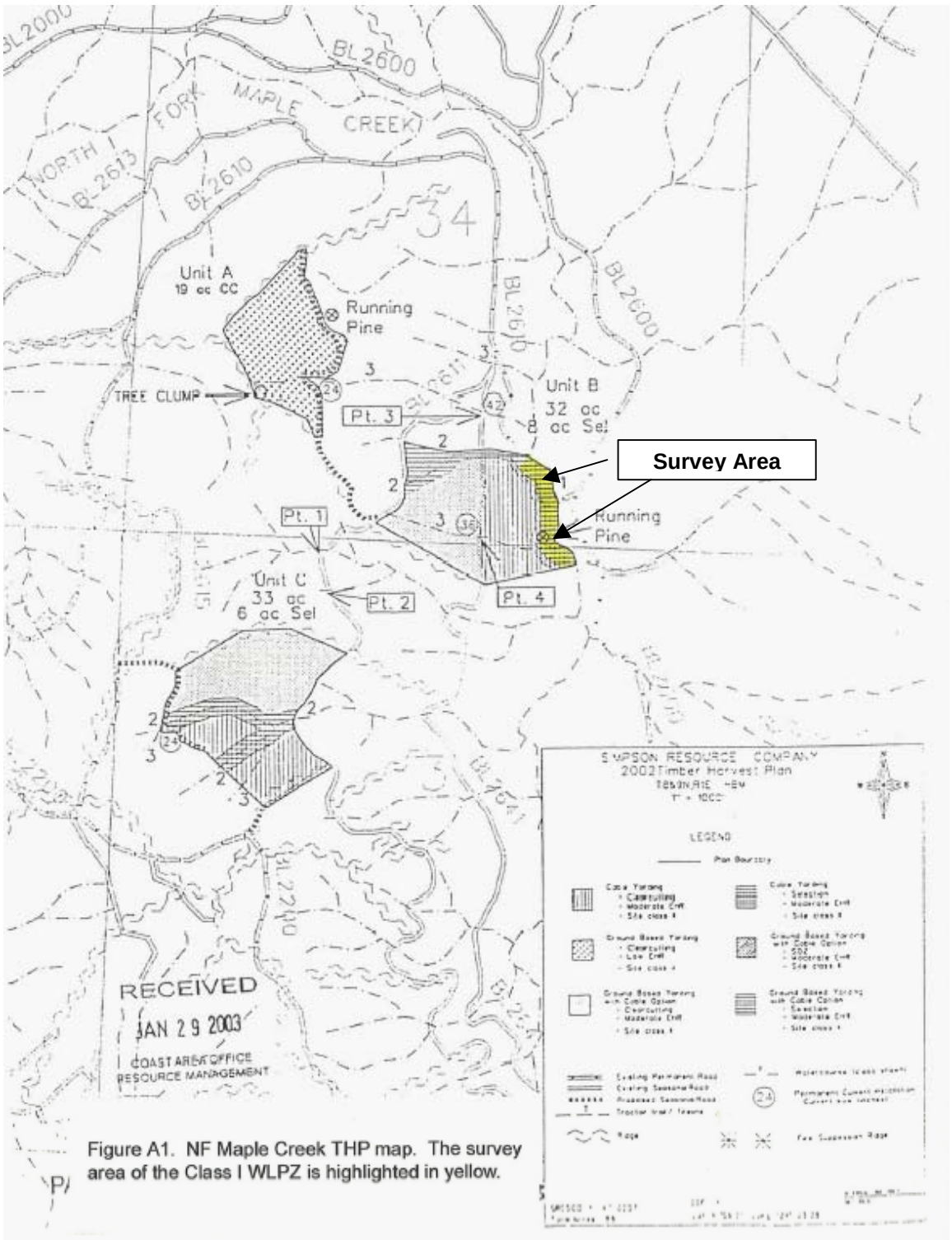

Figure A1. NF Maple Creek THP map. The survey area of the Class I WLPZ is highlighted in yellow.

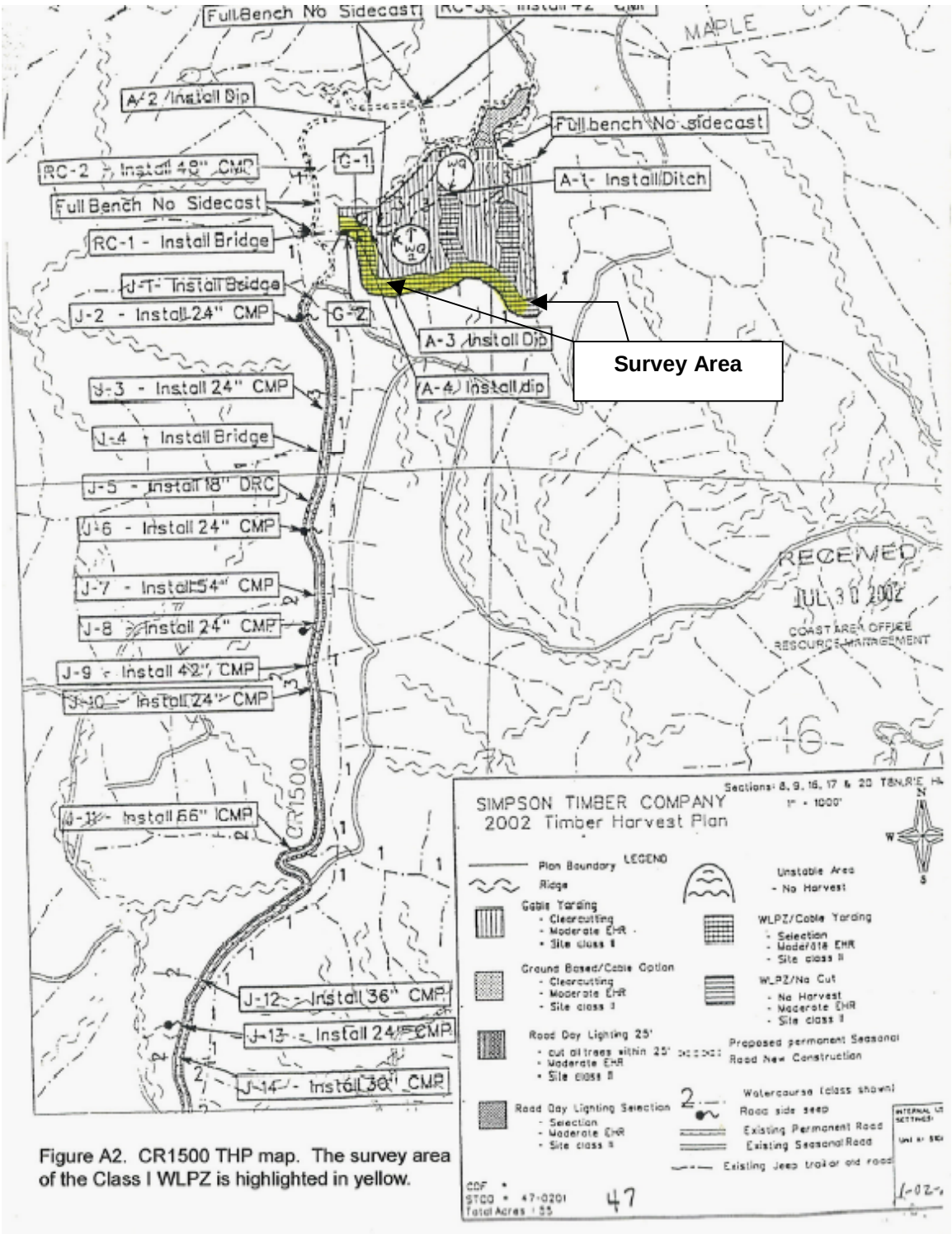

Figure A2. CR1500 THP map. The survey area of the Class I WLPZ is highlighted in yellow.

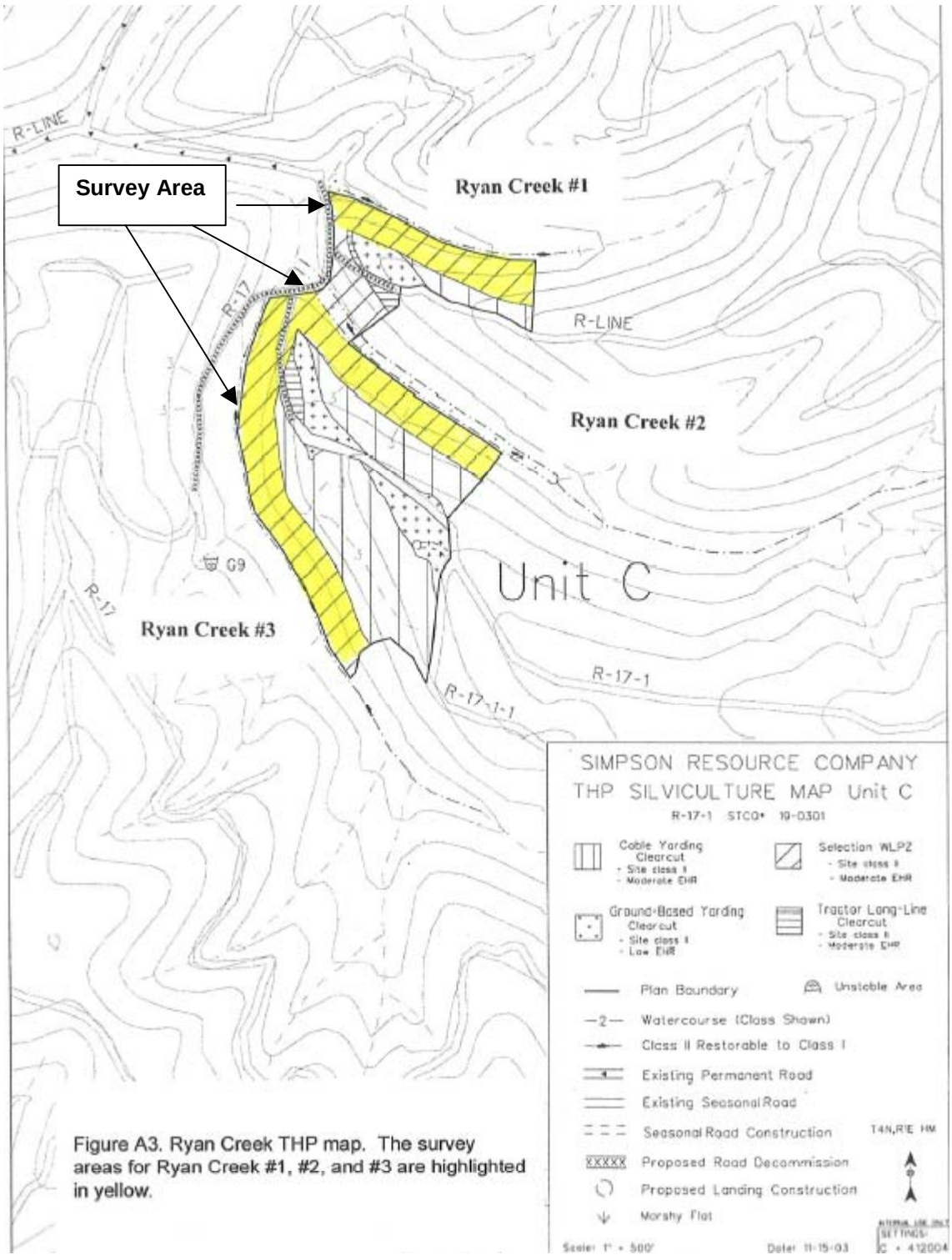

Figure A3. Ryan Creek THP map. The survey areas for Ryan Creek #1, #2, and #3 are highlighted in yellow.

Attachment B

Summary data

Table B1. Full Tree Equivalents (FTE) and associated summary information for each WLPZ.

	Ryan #1	Ryan #2	Ryan #3	CR1500	NF Maple
Zone survey length (feet)	1086	1203	1689	2183	1299
Total # of live and recently harvested conifers in zone	296	420	521	1115	251
# of redwood	168	342	426	982	184
# of Douglas fir	126	76	95	129	23
# of other conifer	2	2	0	4	44
Total # of live trees marked or recently harvested	8	10	10	88	5
# of redwood	2	7	9	81	5
# of Douglas fir	6	3	1	7	0
# of other conifer	0	0	0	0	0
Percent conifer retention	97.30	97.62	98.08	92.11	98.01
Current Full tree equivalents (FTE)					
Pre-harvest	56.65	88.36	124.19	134.51	28.30
Post-harvest	56.37	88.16	123.95	133.68	28.30
Percent reduction	0.48	0.23	0.19	0.62	0.00
# of harvested trees with a FTE value >0.0 (current)	7	7	7	14	0
Predicted Full tree equivalents (+ 50 years)					
Pre-harvest	75.86	111.61	153.57	204.38	41.99
Post-harvest	74.95	110.72	152.59	201.15	41.87
Percent reduction	1.20	0.80	0.63	1.58	0.29
# of harvested trees with a FTE value >0.0 (+ 50 years)	8	10	10	44	4
# of trees with obvious lean ($\geq 5^0$)	53	100	171	166	55
Range of lean from vertical (degrees)	5 - 60	5 - 50	5 - 55	5 - 60	5 - 46
# of trees with downslope lean ($0\text{-}179^0$)	39	69	122	112	26
# of trees with upslope lean ($180\text{-}359^0$)	14	31	49	54	29
Channel gradient (%)	2.2	2	2	2	3
Slope gradient range (%)	35 - 76	0 - 82	0 - 62	5 - 100	3 - 18

Table B2. Diameter and height summary of conifers and snags for each WLPZ.

	Ryan #1	Ryan #2	Ryan #3	CR1500	NF Maple
Average diameter of WLPZ conifers (inches)	24.1	29.1	26.7	20.8	21.7
Redwood	23.1	27.7	25.8	21.0	23.0
Douglas fir	25.5	35.5	31.1	19.3	18.9
Other conifer	12.0	36.0	none	20.0	17.6
Average diameter harvested conifers (inches)	22.8	31.1	33.2	23.2	31.8
Redwood	28.0	29.3	33.0	22.9	31.8
Douglas fir	21.0	35.3	35.0	26.6	none
Other conifer	none	none	none	none	none
Live conifer diameter range (inches)	10 - 56	10 - 100	10 - 78	10 - 80	10 - 60
Redwood	10 - 56	10 - 100	10 - 78	10 - 80	10 - 52
Douglas fir	10 - 48	10 - 100	10 - 64	10 - 50	10 - 36
Other conifer	12	23 - 49	none	12 - 30	10 - 60
Harvested conifer diameter range (inches)	11 - 34	22 - 41	18 - 52	8 - 47	25 - 39
Redwood	22 - 34	22 - 36	18 - 52	8 - 47	25 - 39
Douglas fir	11 - 28	32 - 41	35	24 - 31	none
Other conifer	none	none	none	none	none
Average height of WLPZ conifer (feet)	139	138.5	135.0	92.7	87
Redwood	119.9	130.7	126.7	88	84.2
Douglas fir	161.7	174.1	172.0	127.3	95.7
Other conifer	126.6	177.3	none	129.1	94.2
Live Conifer height range (feet)	75.5 - 189.9	75.5 - 226.7	75.5 - 209.4	58.1 - 164.3	53.4 - 131.2
Redwood	75.5 - 186.1	75.5 - 226.7	75.5 - 209.4	58.1 - 164.3	53.4 - 126.2
Douglas fir	100.7 - 189.9	126.7 - 209.2	126.7 - 198.2	104.1 - 162.8	80.3 - 131
Other conifer	126.6 - 135.5	164 - 190.5	none	111.7 - 146.4	80.3 - 131.2
# of snags	21	33	36	29	6
Redwood	7	16	26	22	6
Douglas fir	14	9	10	7	0
Other conifer	0	0	0	0	0